



Flight Performance of a Functionally Gradient Material, TUF1, on Shuttle Orbiter

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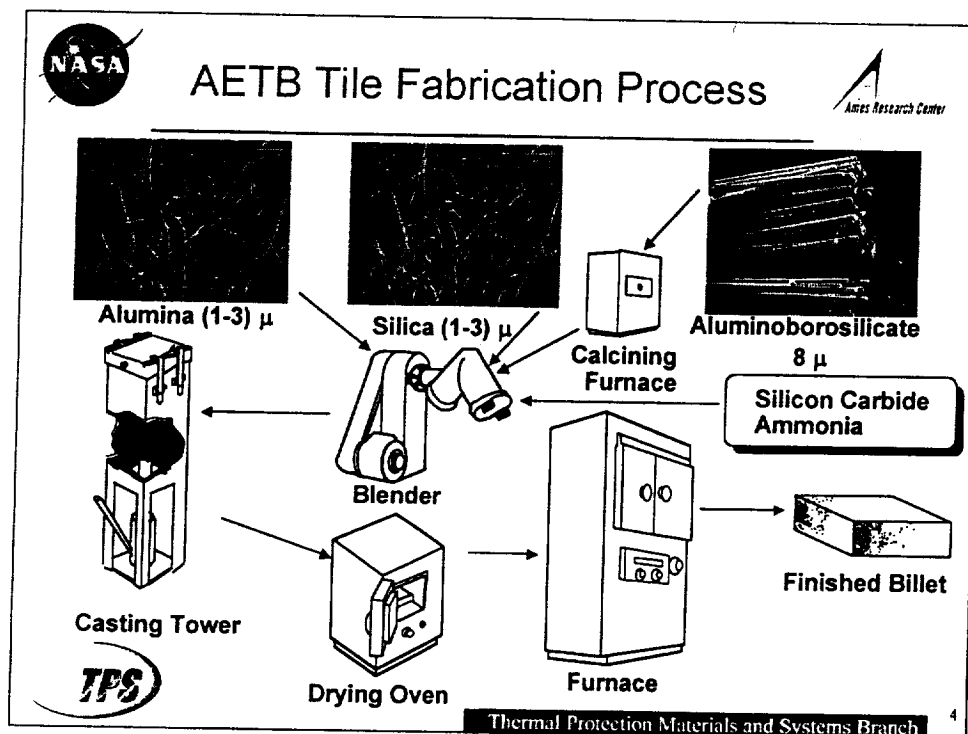
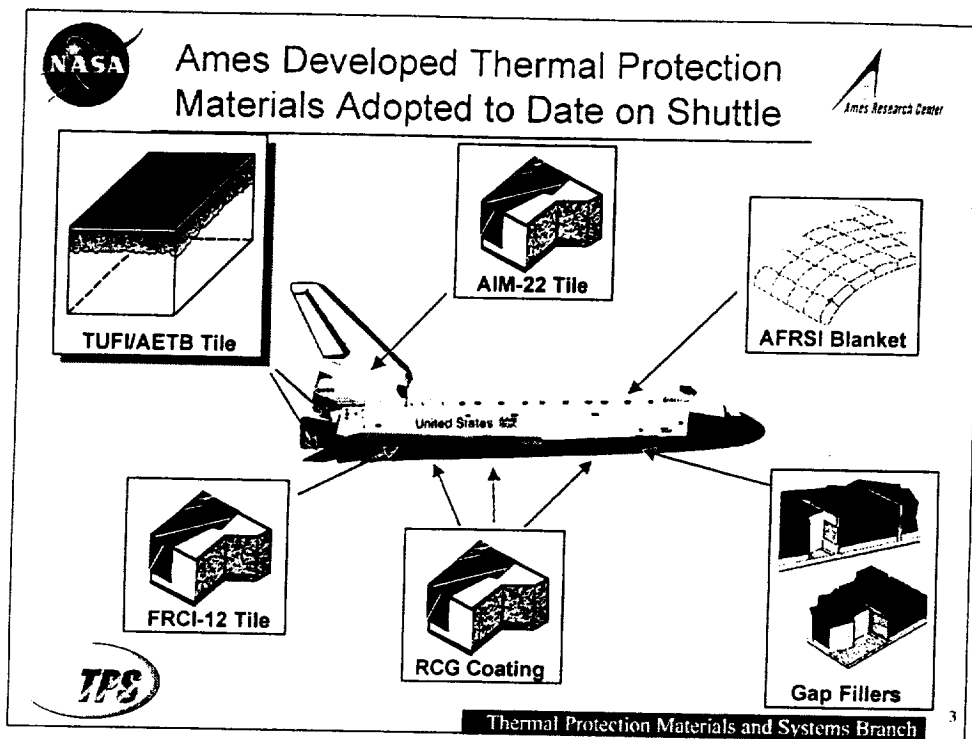
Outline

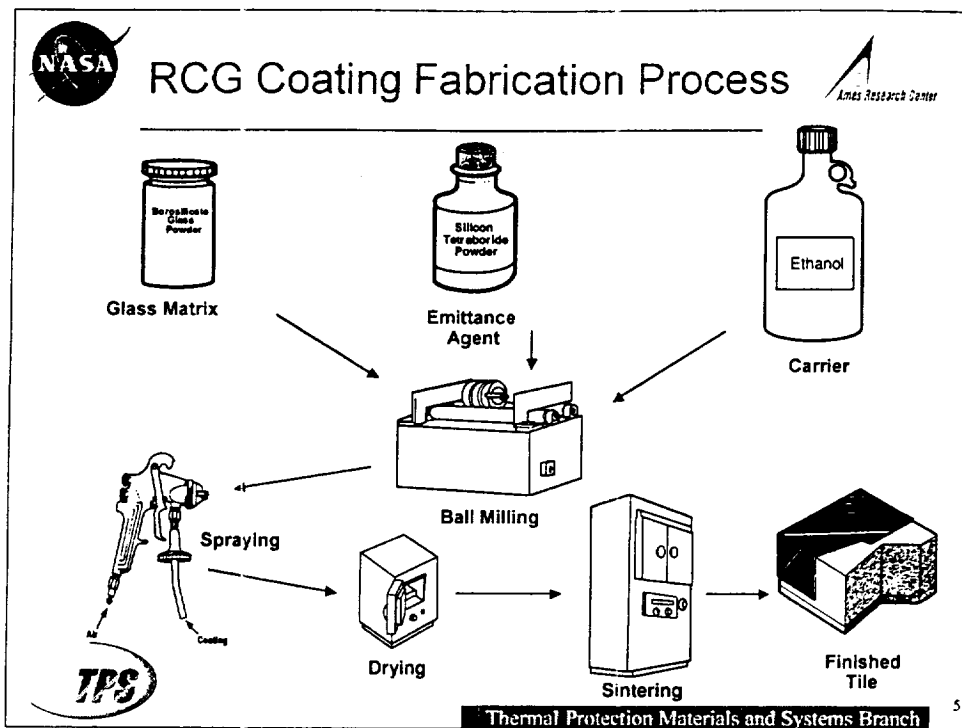


- Introduction
 - Ames Research Center Contributions
 - Coating/Insulation Materials
 - Performance Comparison
- Initial TUF1 Flight Experiment
- Performance of TUF1 in Other Selected Areas
- Current Status
- Summary



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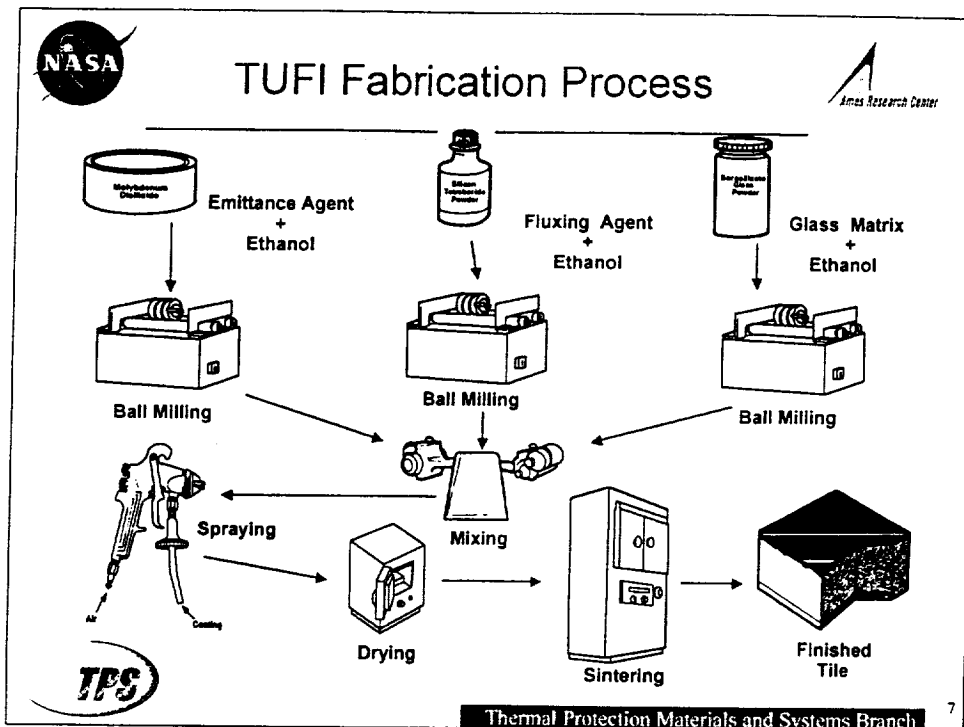


NASA Reaction Cured Glass (RCG) Coating *Ames Research Center*

- High Emittance $\epsilon > 0.8$
- 0.38 mm thick
- Compatible with silica tiles
 - no devitrification
 - match tiles CTE
- RCG coating sits on top of tile surface
 - particle size too large to infiltrate
- Dense coating
 - initial moisture barrier
- Poor impact resistance.

TPS

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Toughened Uni-Piece Fibrous Insulation (TUFI)

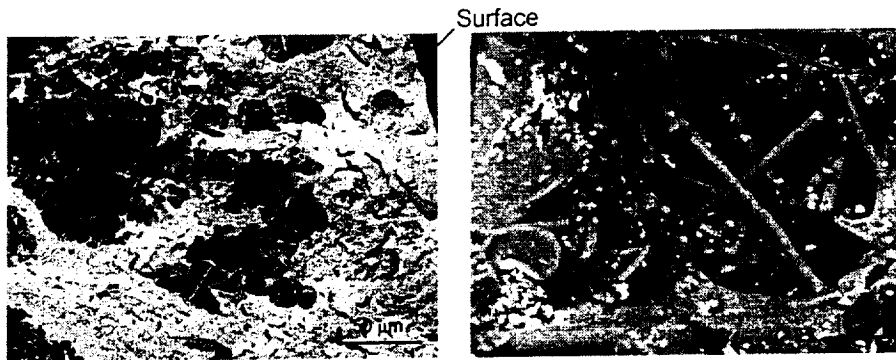
- High Emittance $\epsilon > 0.8$
- 2.5 mm thick
- Compatible with tile
 - no devitrification
- Porous coating
- Material penetrates into the tile
 - smaller particle size
- Significantly improved impact resistance
- MoSi₂ acts as emissivity agent
 - also increases CTE so it matches that of AETB tiles.

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Microstructure of TUF1 System



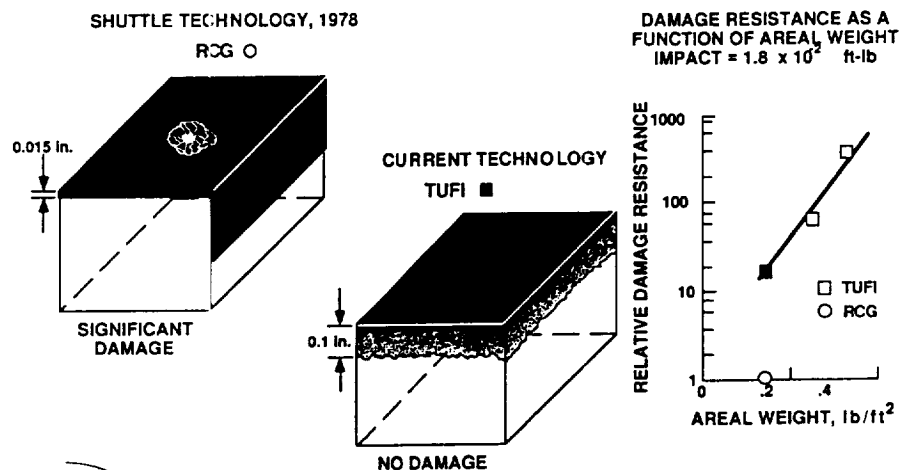
- TUF1 is applied as three separate coats.
- Results in a graded coating system that is denser near the surface.
- Two scales of porosity
 - regions that appear deficient in glass
 - denser regions also have a smaller scale porosity

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Impact Resistance Comparison of Tile Coating Systems

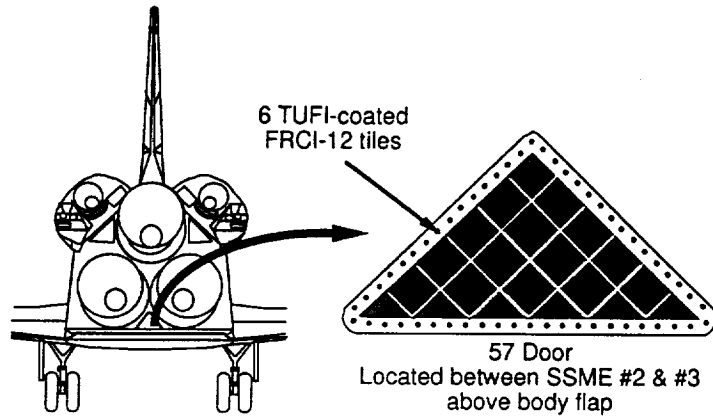


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Location of TUF1/FRCI-12 Tiles on Base Heatshield Panel

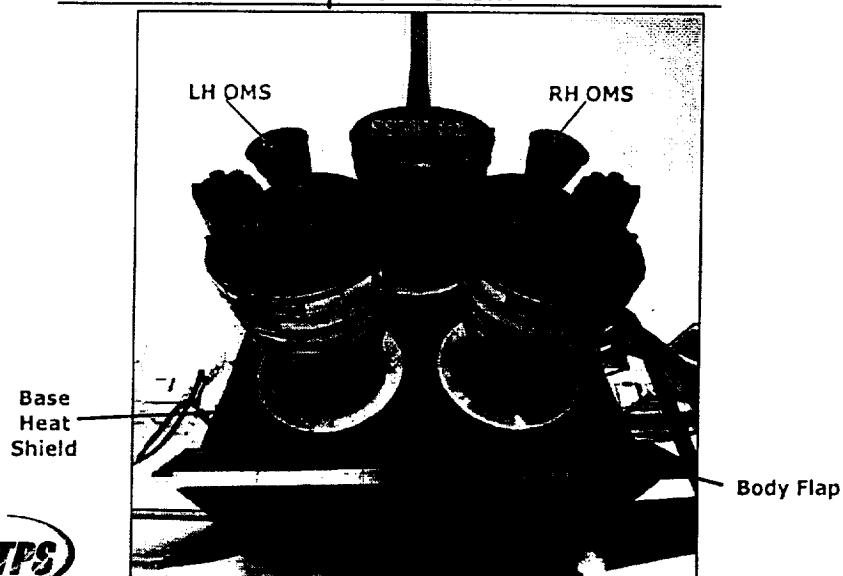


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Base Heat Shield Upper Body Flap Overall

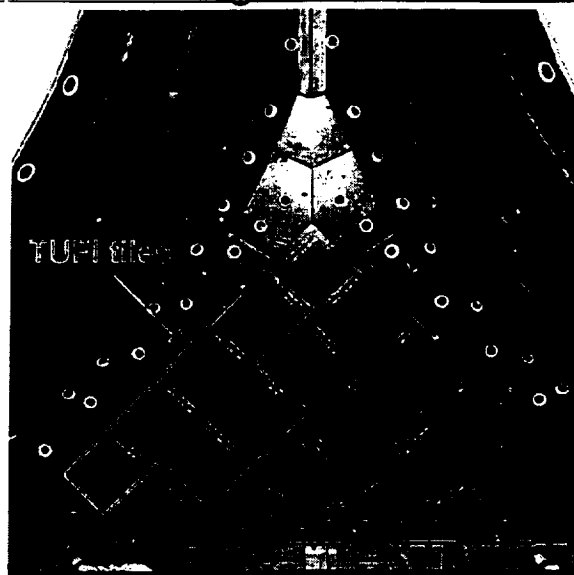


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TUFI/FRCI-12 Panel After First Flight

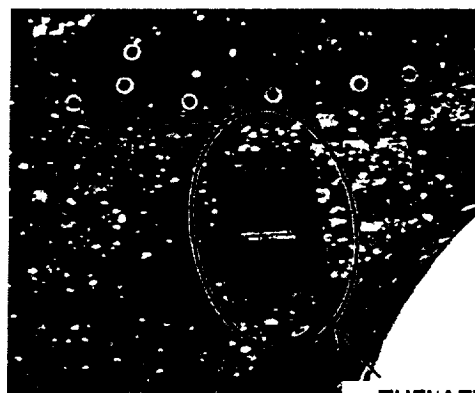


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Shuttle Base Heat Shield Flight Testing of TUFI on AETB Tile Substrate, STS-59



**TUFI/AETB-8 Tiles
Undamaged After
Three Flights**

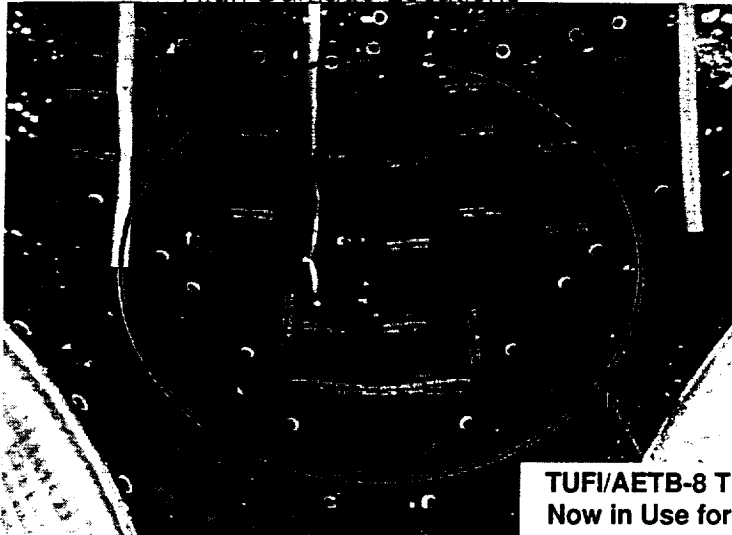


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TUFI/AETB-8 Tiles Adopted on all Orbiters for Base Heat Shield, Upper Body Flap and Other High Damage Locations



**TUFI/AETB-8 Tiles
Now in Use for All
Base Heat Shields**



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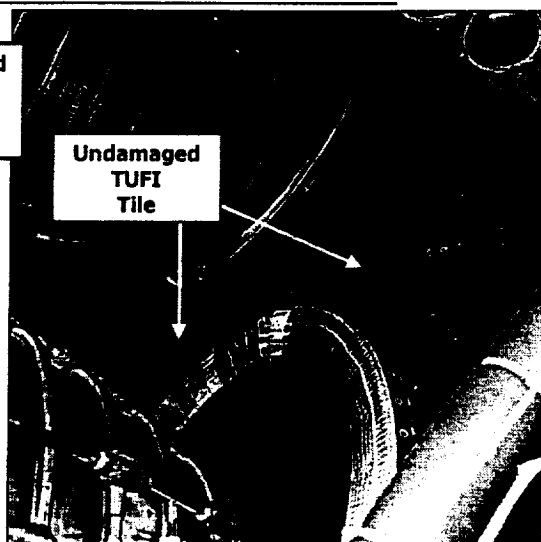
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Base Heat Shield Pre/Post TUFI



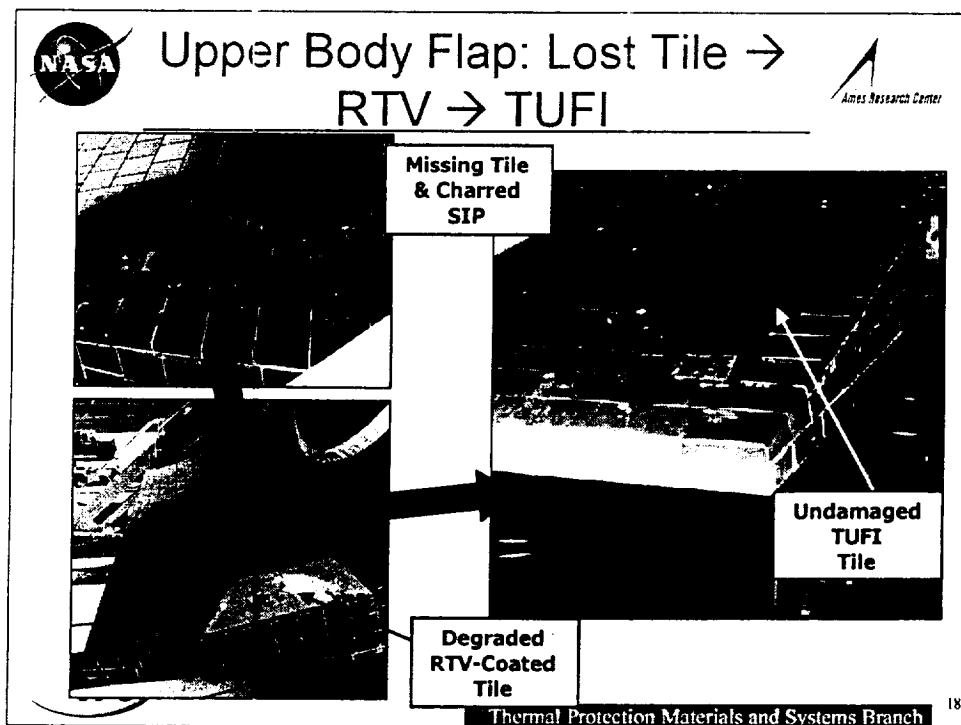
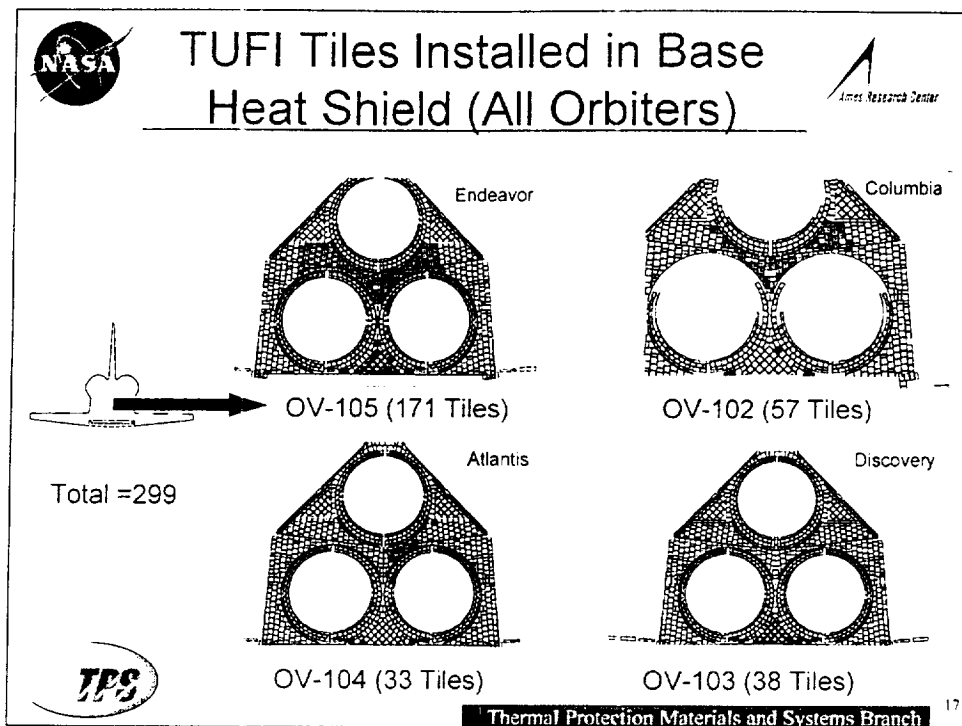
**Degraded
Repairs
and
Damage**

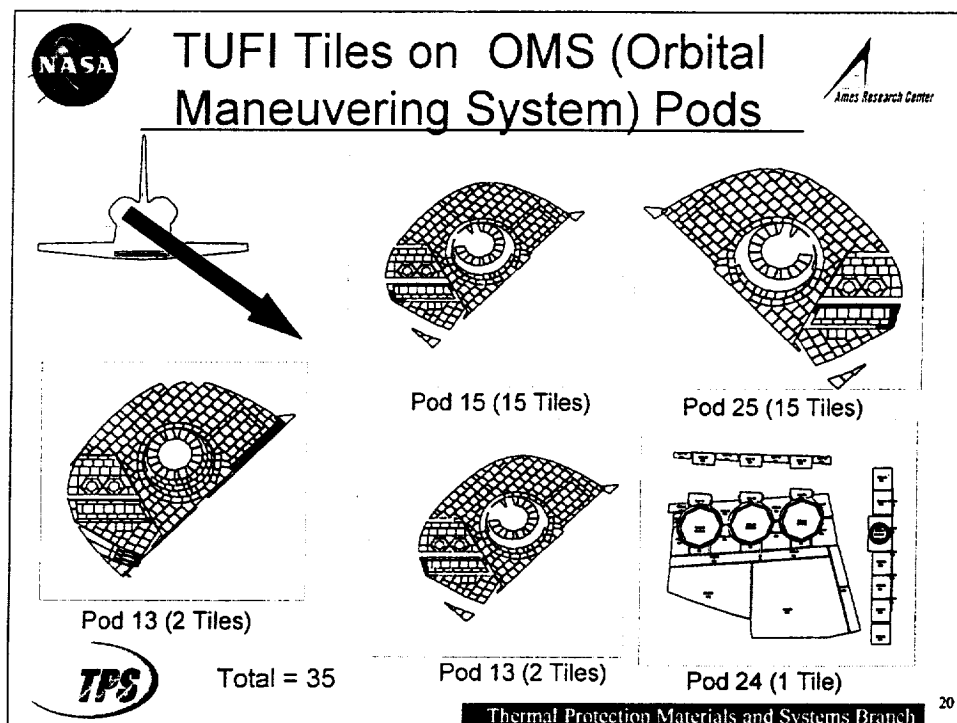
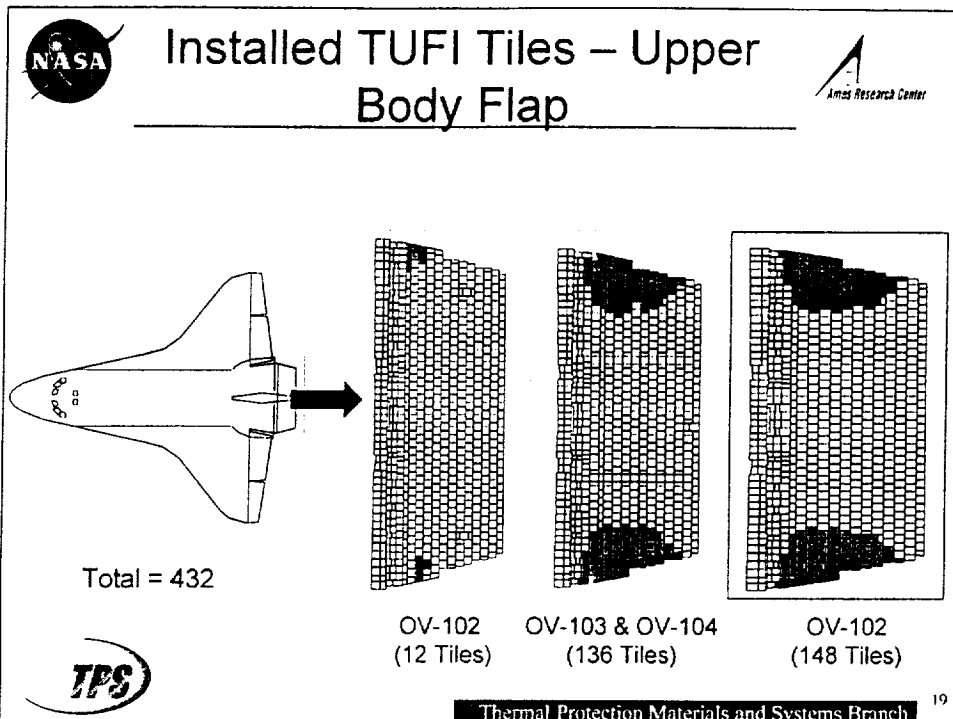


**Undamaged
TUFI
Tile**

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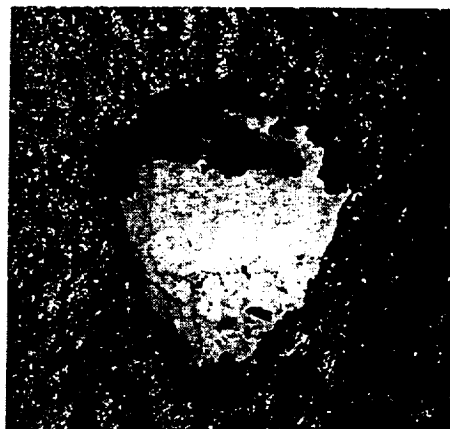
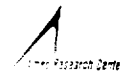
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OV-102 TUFI Tile Damage

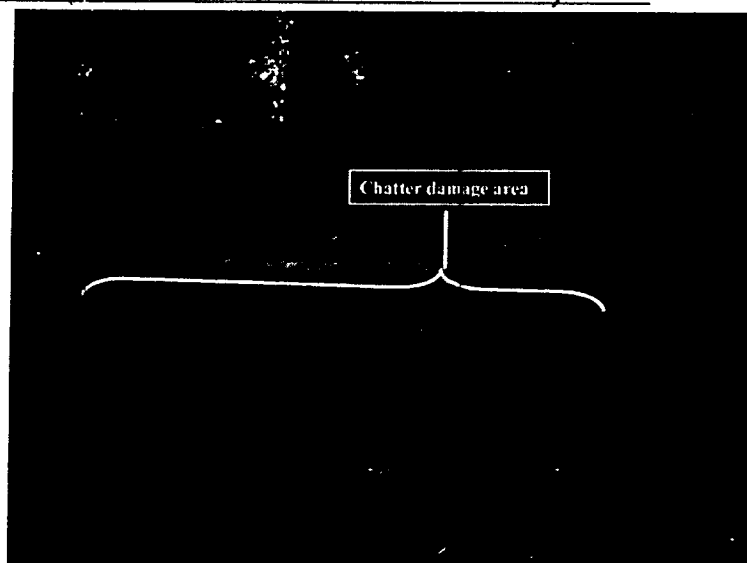


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OV-105 Tile Chatter Damage (~ 1.0" L x .7" W x .1" D)

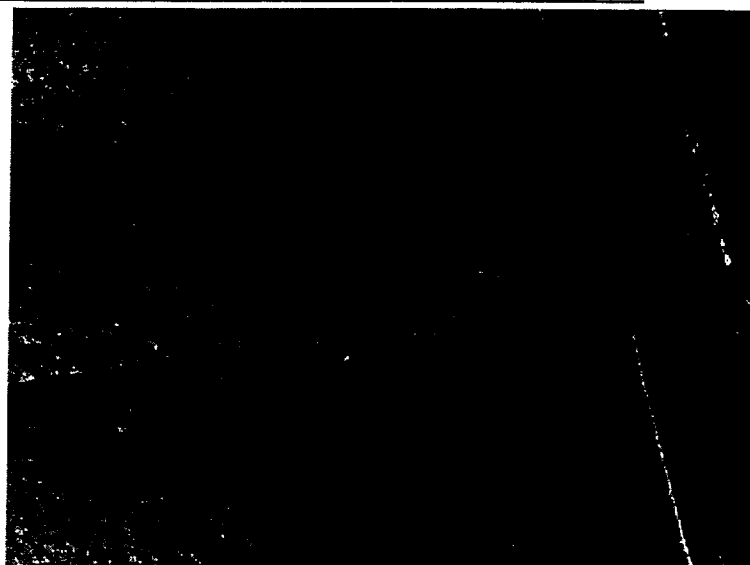


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OV-104 Tile Chatter Damage to RCG Overcoat



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Summary



- An order of magnitude improvement in flight performance has been demonstrated in TUF1, a graded porous surface treatment for RSI when compared on the Shuttle Orbiter to the baseline RCG, a fully dense glass surface coating.
- 766 TUF1 tiles have been applied and flown in various locations on all 4 Orbiters
- Usage has expanded into high damage areas on an attrition basis as funding has become available and the financial benefits can be demonstrated



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